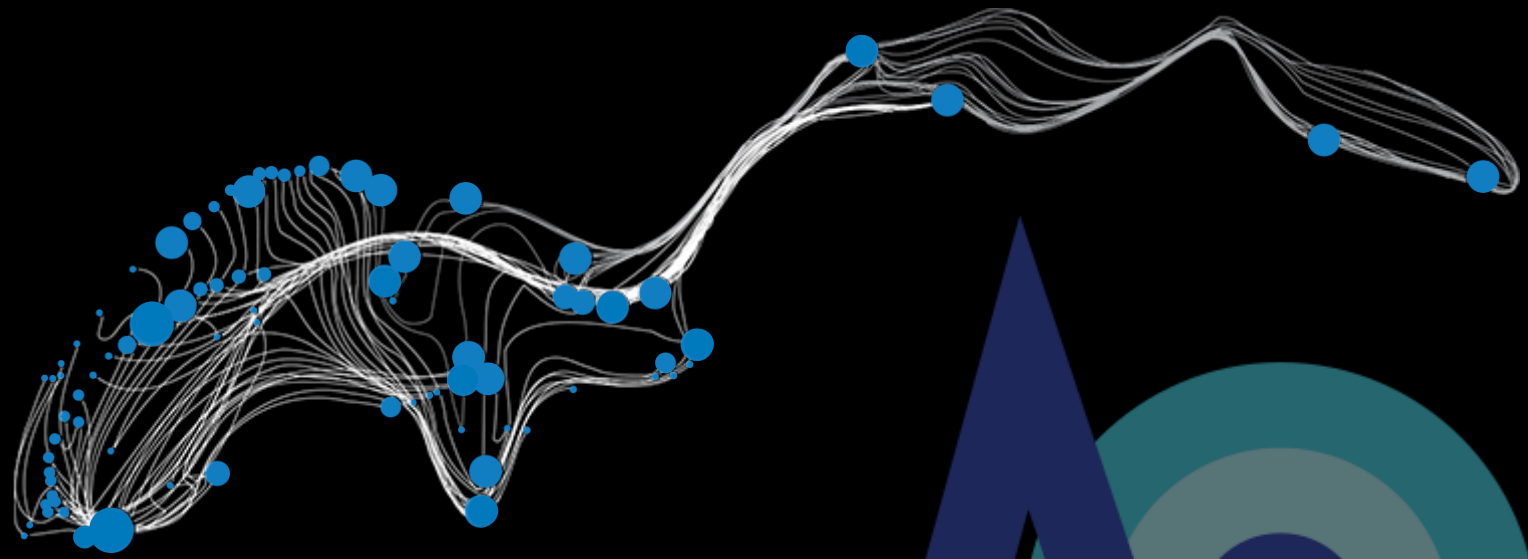
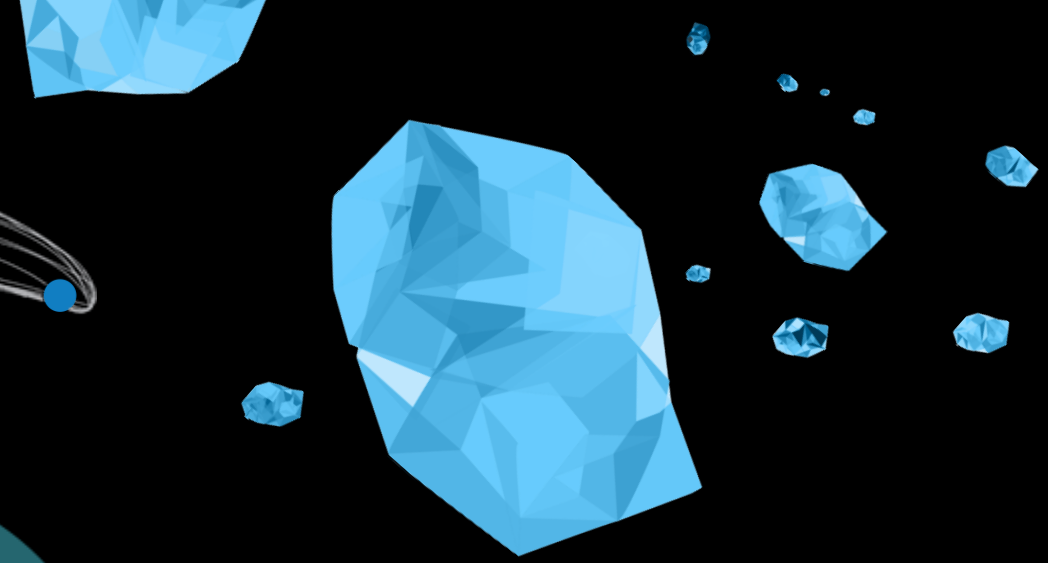
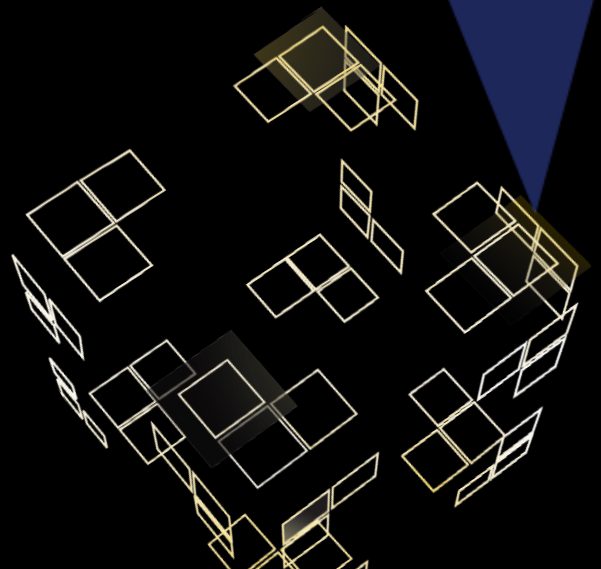


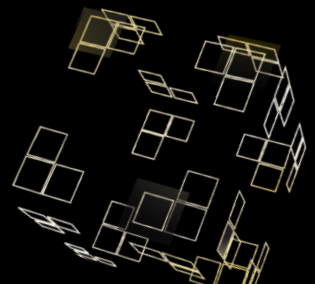


Introduction to Sensors

Industry 4.0 with Human Touch, Technology course

By Fjodor van Slooten





UNIVERSITY OF TWENTE.

CONTENT

Introduction to Sensors

- Introduction to ‘Sense’
- Sensor types
- Industrial Sensors
- Application in production environments/factories
- Industry 4.0
- Practical

Contact: f.vanslooten@utwente.nl

This presentation & tutorials available at:
vanslooten.com/i40 or via Canvas

‘SENSE’

- Why?
- Need to know something (of your environment)

- What?
- In industry: measure process

‘sensor’ detects carbon monoxide

Five Senses of Sensors (human/biology)

Sound, Vision, Taste, Smell, and Touch

There are more: e.g. balance & acceleration, temperature, proprioception, pain, …

ⓘ wikipedia.org/wiki/Sense

Machine Sensors

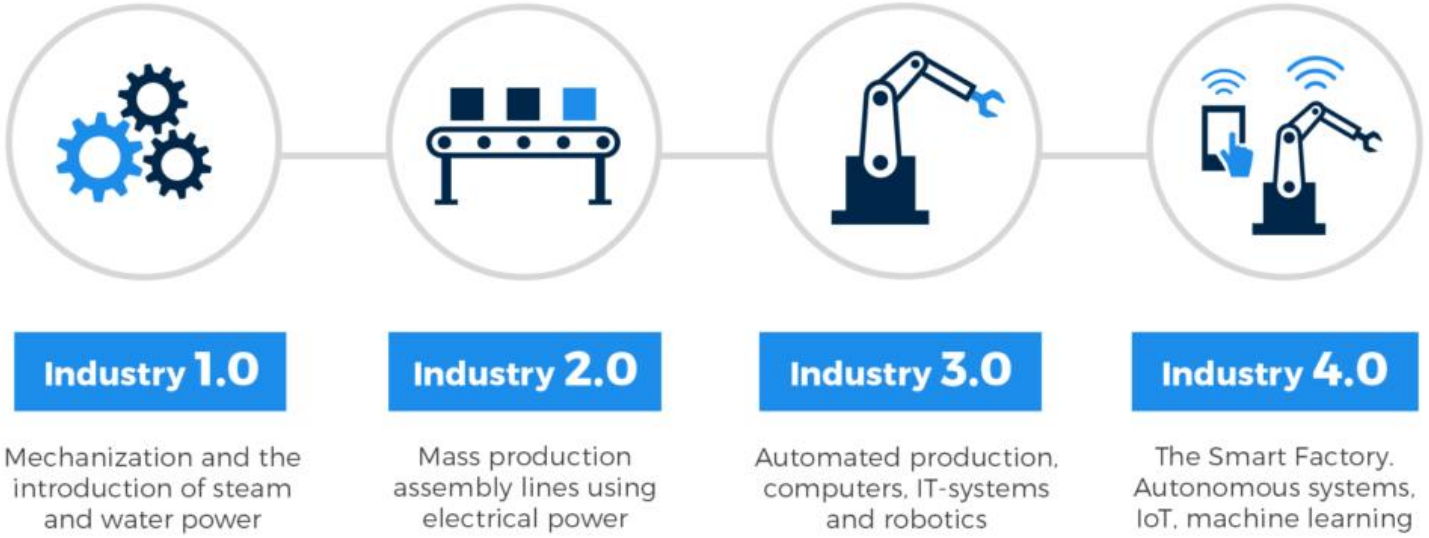
"… a sensor is a device, module, machine, or subsystem whose purpose is to **detect events or changes in its environment** and send the information to other electronics, frequently a computer processor…"

wikipedia.org/wiki/Sensor

- Electromagnetic spectrum (frequency spectrum): radio, sound, light
- Chemical: sense chemical compounds, capacitive
- Mechanical: touch, rotate, bend, accelerate...
- Combined (smart): include processor, eg. ultrasonic sensor: calculates distance

‘Sense’ - conclusion

- There are infinite types of sensors and lots of senses (types).
- This lecture is *only an introduction*: you will have to **do research** for your own application/assignment!



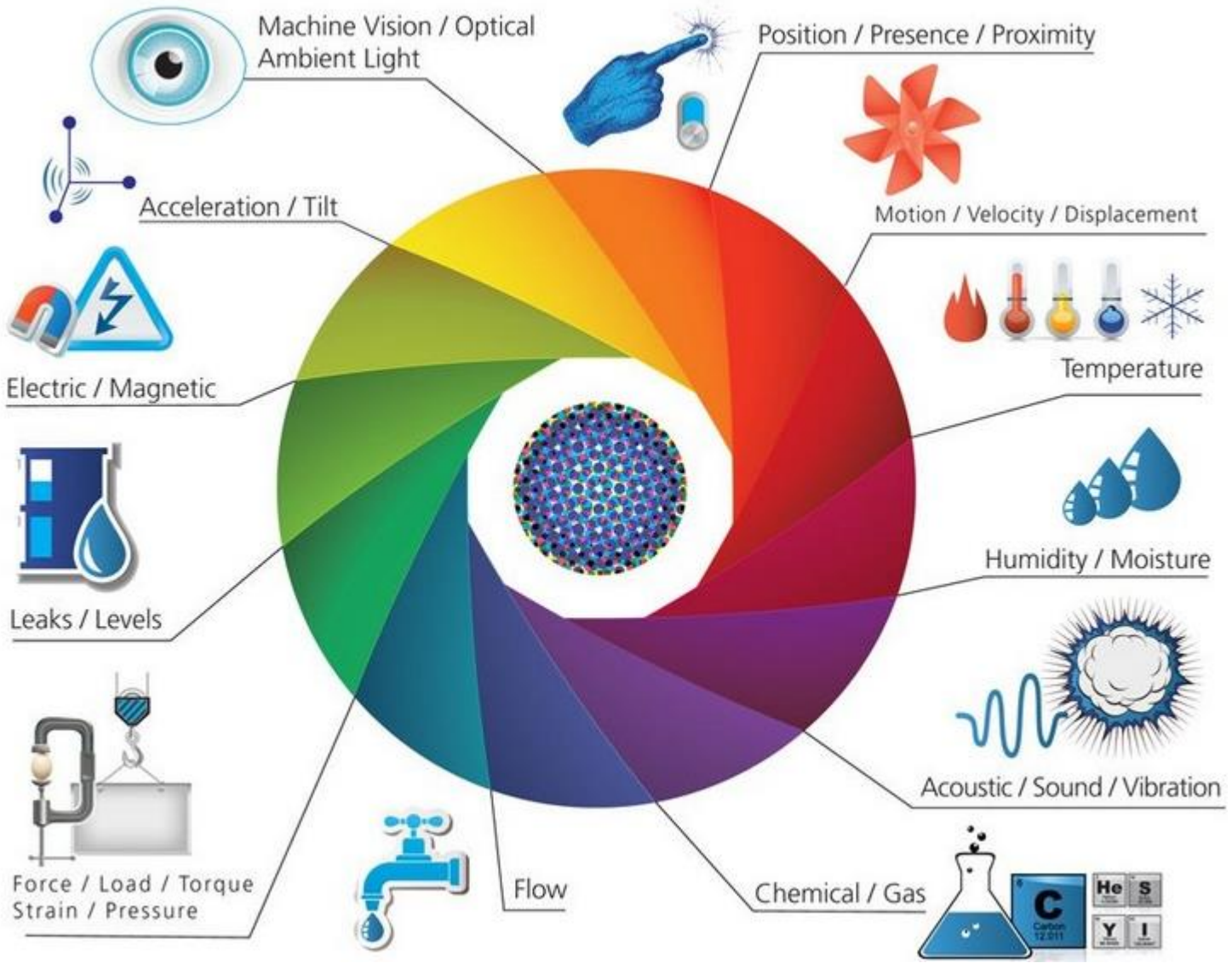
www.spectralengines.com/articles/industry-4-0-and-how-smart-sensors-make-the-difference

ⓘ [The Five Senses of Sensors—Part I: Smell, Taste, and Hearing]
[The Five Senses of Sensors—Part II: Touch and Vision]
[How Sensors Make Sense]
[The Evolution of Sensors: Canaries to Drones]
[Industry 4.0 and how smart sensors make the difference]

SENSOR TYPES

Focus

Industrial, Professional, Consumer

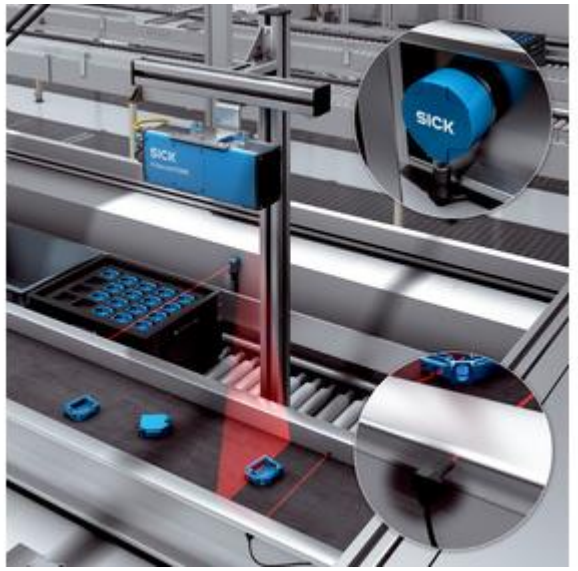


blackboxparadox.com/2016/12/19/iot-sensor-classification

Examples: conveyor belts

Monitoring conveyor belt speed

Belt speed is controlled using the measured values of a programmable incremental encoder.



Quality and position monitoring on conveyor belts

In order to grip objects on moving conveyor belts, a pick-and-place robot requires an image processing system that gives it the ability to “see.” A programmable 3D vision sensor is a reliable solution under difficult conditions.

Photoelectric distance sensor

[Product page W16]

Technical details | Downloads | Accessories | Videos | Service and Support | Customs data

Show all | Hide all

FEATURES

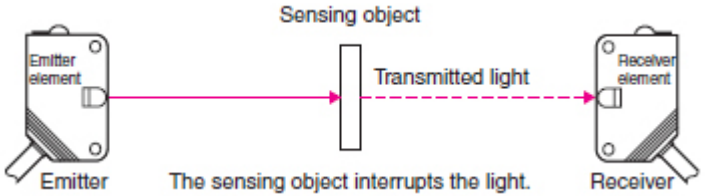
Sensor/ detection principle	Photoelectric proximity sensor, Background suppression
Dimensions (W x H x D)	20 mm x 55.7 mm x 42 mm
Housing design (light emission)	Rectangular
Sensing range max.	10 mm ... 1,500 mm [1]
Type of light	Infrared light
Light source	LED [2]
Light spot size (distance)	Ø 12 mm (800 mm)
Wave length	850 nm
Adjustment	BluePilot: Teach-Turn adjustment with sensing range indicator IO-Link
Pin 2 configuration	External input, Teach-in, switching signal

[1] Object with 90 % reflectance (referred to standard white, DIN 5033).
[2] Average service life: 100,000 h at T_U = +25 °C.

+ MECHANICS/ELECTRONICS
+ SAFETY-RELATED PARAMETERS
+ CLASSIFICATIONS
+ SMART TASK
+ COMMUNICATION INTERFACE

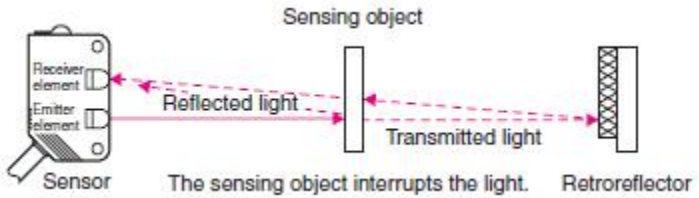
How does a photoelectric sensor work?

Through-beam Sensors

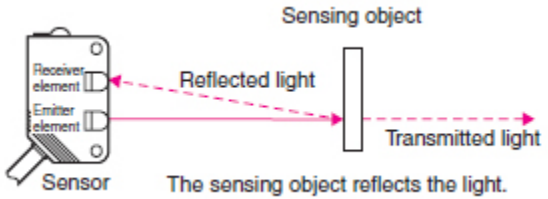


Ultrasonic sensors use same principle, but use (ultrasonic) sound instead of light

Retro-reflective Sensors



Diffuse-reflective Sensors



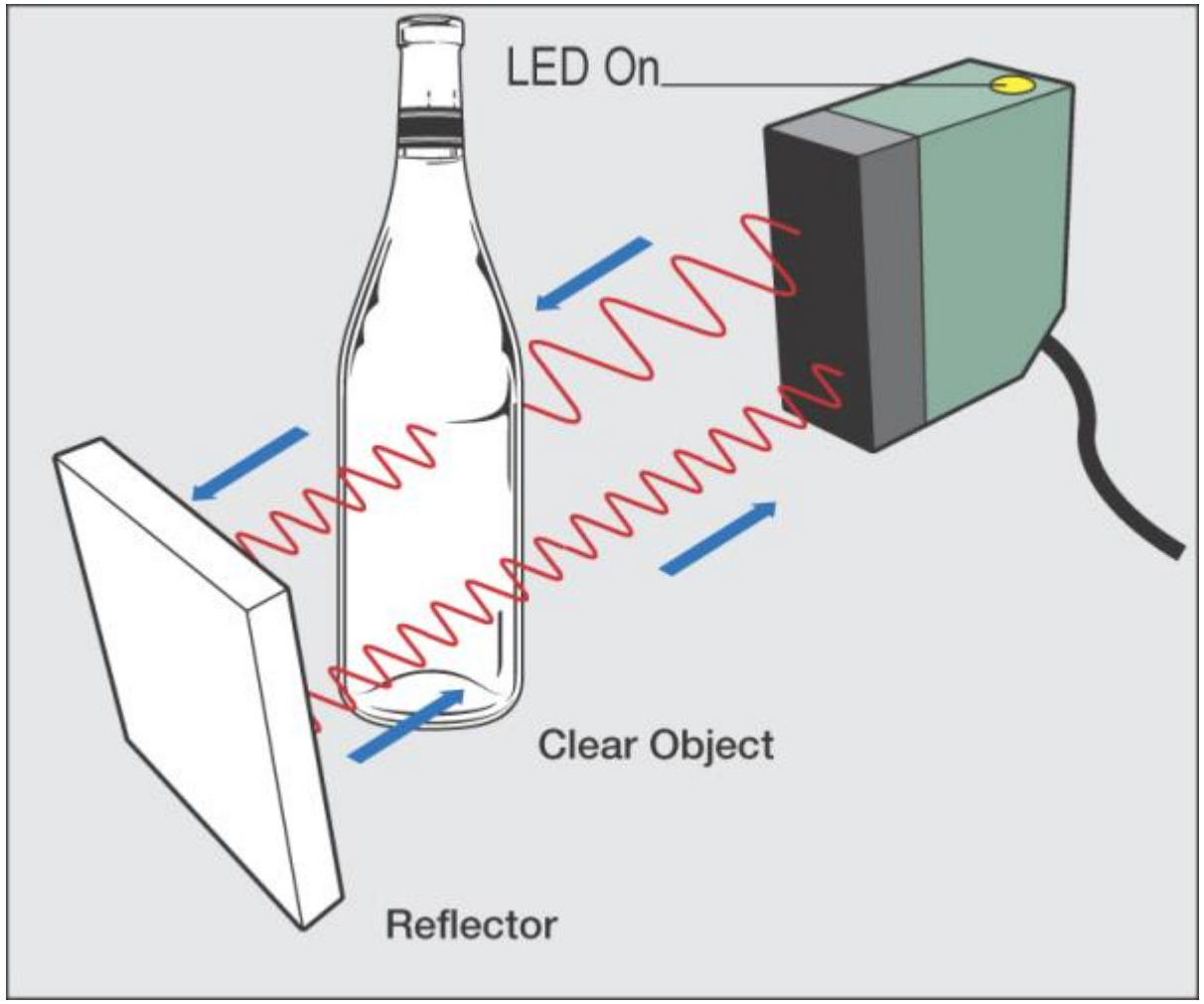
Read more @ Omron website

Clear Object Detection

- Special variant of the standard, retroreflective sensor
- Amount of light that returns is slightly less
- Sensor must be sensitive

Learn more

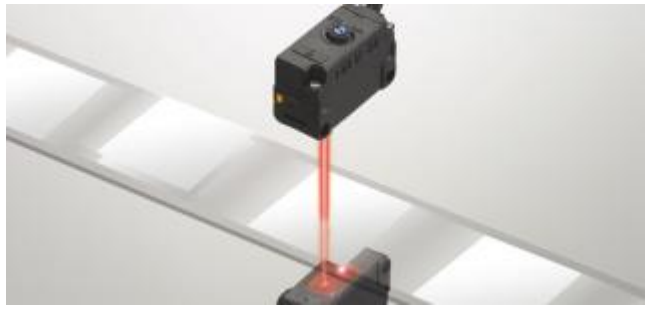
Or watch video

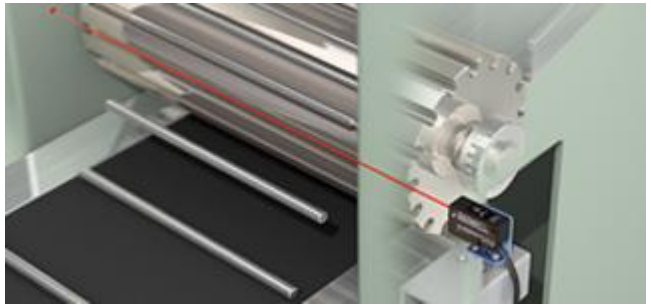


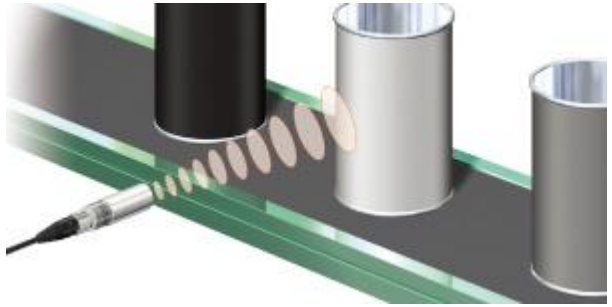
blog.pepperl-fuchs.us/blog/bid/250978/Clear-Object-Detection-with-Photoelectric-Sensors

INDUSTRIAL SENSORS

- Proximity sensors
- Photoelectric sensors
- Ultrasonic sensors
- Rotary encoders
- Positioning systems
- Inclination and acceleration sensors
- Identification systems
- Vision sensors
- More…







Images courtesy of Keyence

Manufacturers

KEYENCE
Sensor basics & selection

PEPPERL+FUCHS
Products & intro to technologies

SICK
Product portfolio & know-how

More...

Images courtesy of Sick, Pepperl+Fuchs

Choosing sensors

- Scenarios: when to apply what? (choosing type of sensors)
- What do sensors actually do/measure?
- What properties do they have?
- Sample-speed: if you use a slow sensor on a high-speed conveyor belt...
- If sensor uses light(-beam) can this be used on glass-products? (eg. bottles)
- What could possibly go wrong?
- Errors in measurements... how to prevent?
- Validity
- Reliability

KEYENCE
Sensor basics & selection

PEPPERL+FUCHS
Products & intro to technologies

SICK
Product portfolio & know-how

Selection criteria: when to use …

- Accuracy (error between result and actual value)
- Repeatability/precision (ability to repeat same values for same input over a number of trials)
- Stability
- Sensitivity
- Range (highest/lowest values)
- Resolution (smallest increment of measure)
- Calibration

Environmental condition

Cost

Power (consumption)

Connectivity

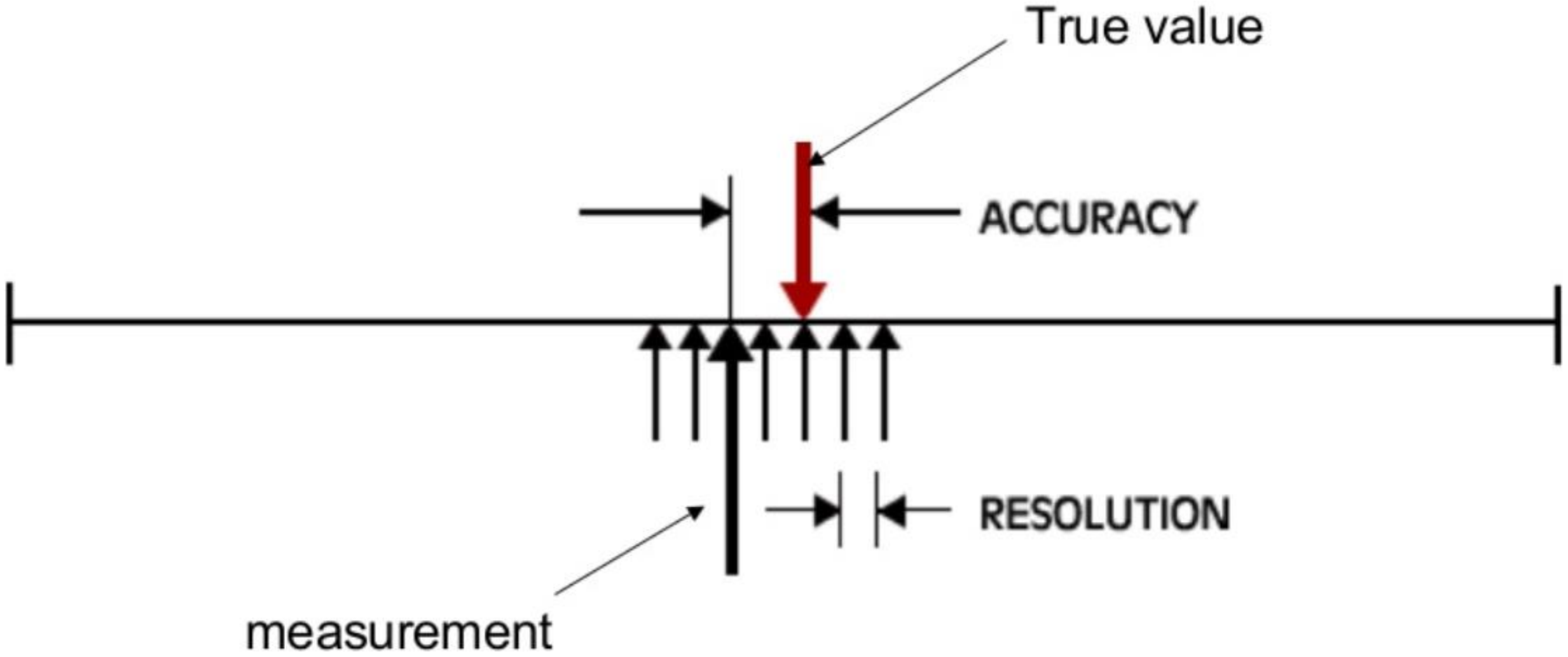
Integration

Standards

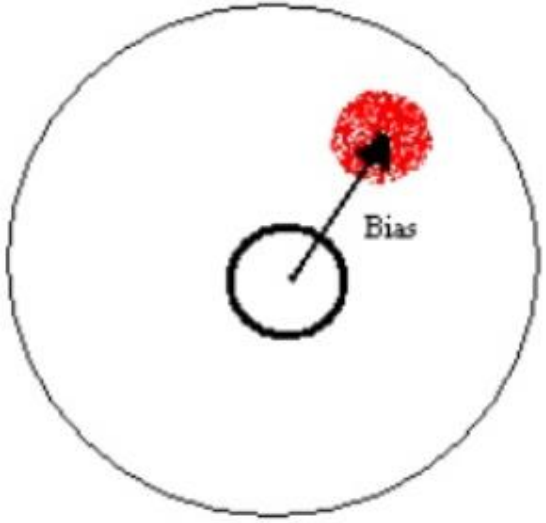
…

TechTip: Accuracy, Precision, Resolution, and Sensitivity

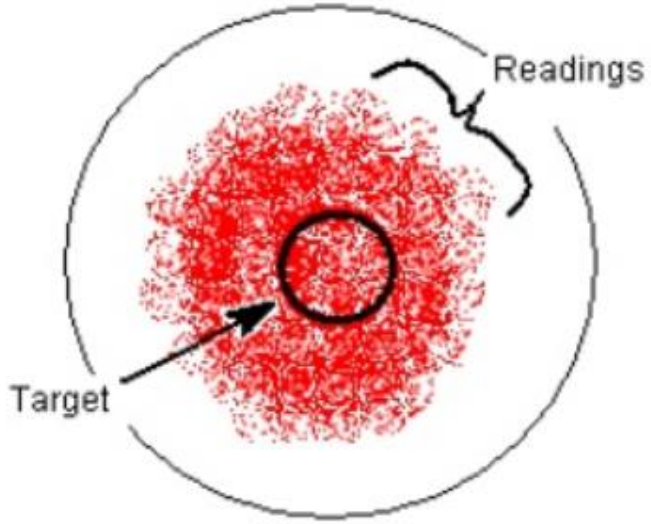
Accuracy vs. Resolution



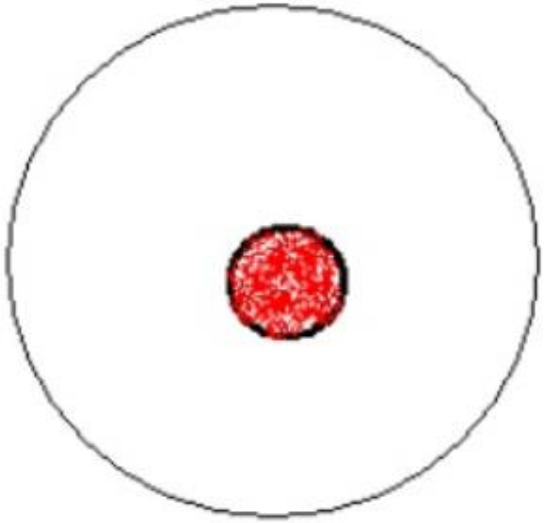
Accuracy vs. Precision



Precision without accuracy



Accuracy without precision

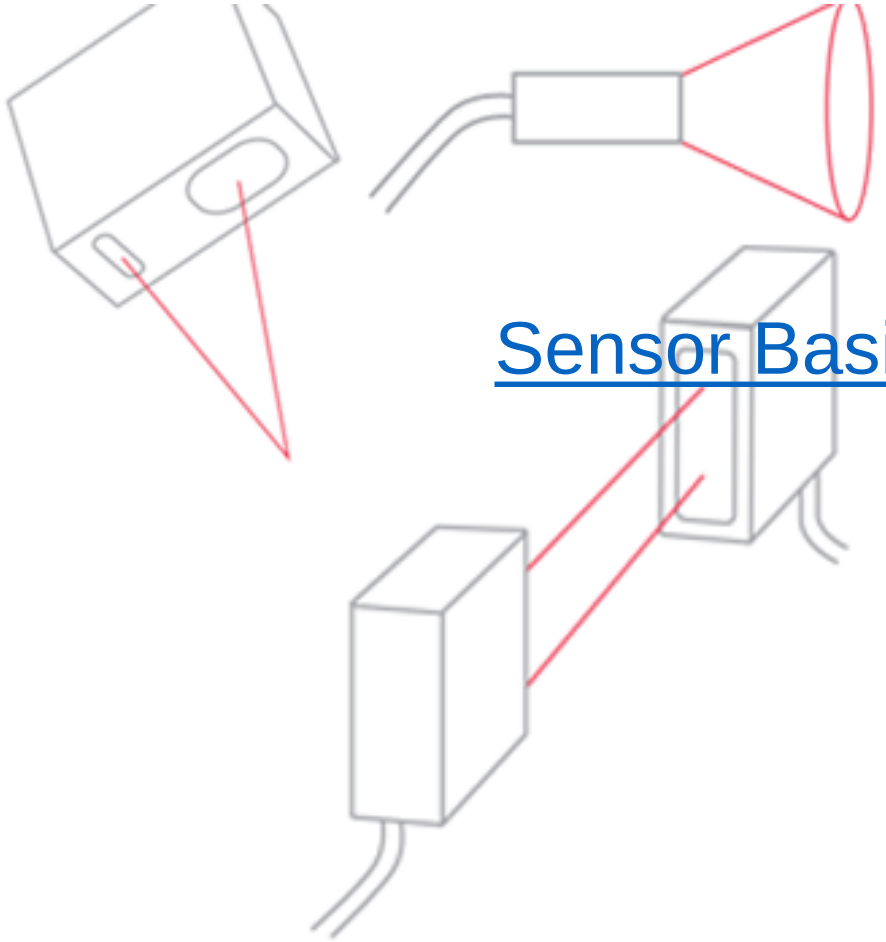


Precision and accuracy

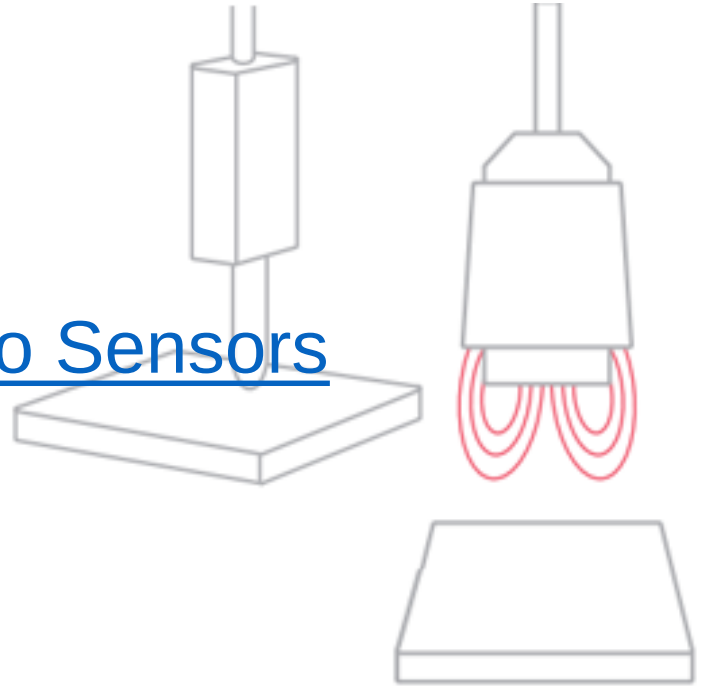
Rules of thumb when selecting

1. **Narrow sensor candidates**. What is the color, shape and material of the target?
2. **How close** can you get **to** the **target?** For close-range applications, use inductive or capacitive sensors. Otherwise, photoelectric or ultrasonic sensors are better.
3. What is the **available voltage supply?** Specify whether sensor will be AC or DC.
4. What will be **near** the **sensor face?** If materials are very close, choose flush or non-flush mounted inductive or capacitive sensors.
5. Consider the **background**'s distance, color, shape, and material. Can anything be mounted here? Is background suppression photoelectric sensing needed, or can the background serve as reflector for retroreflective ultrasonic sensing? Close backgrounds can interfere with inductive or capacitive sensors.
6. For reliable detection, at what **speed and frequency do targets** pass the sensor?
7. **Sensor output styles** vary. Do you need an output when the target is present?
8. What is the **electrical load** you plan to place on the sensor's output powers? A PNP or NPN interface might be required for large loads.
9. Asses the **cleanliness, temperature and moisture** of the sensor **environment** and from that determine the appropriate environmental rating.

Read more



[Sensor Basics: Introductory Guide to Sensors]



APPLICATION

in production environments/factories

www.spectralengines.com/articles/industry-4-0-and-how-smart-sensors-make-the-difference

Areas of Application: Industries

Images courtesy of Pepperl+Fuchs

Application of

Proximity sensors

[measure if an object is near]

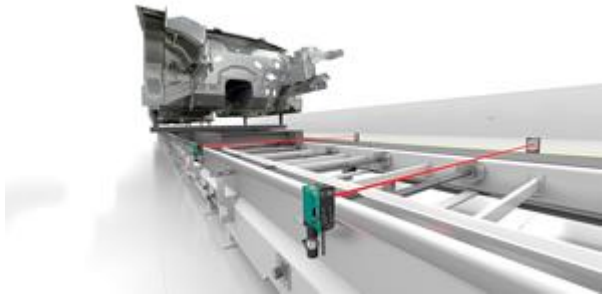
- Inductive
- Capacitive
- Magnetic Field

Detecting metal objects
Positioning machine parts (Valve positioning, On/off switches)
Speed monitoring

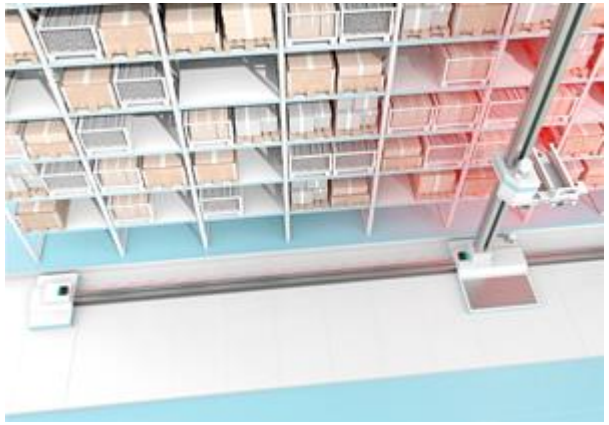
Images courtesy of Pepperl+Fuchs

Application of Photoelectric Sensors

[distance]



Automotive



Material Handling

Machine Engineering

Food and Beverage

Doors, Gates, and Elevators

Application of

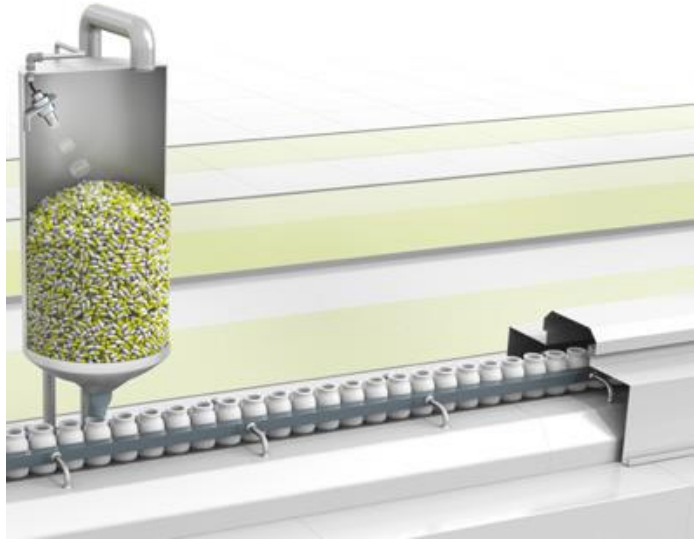
Ultrasonic Sensors

[distance]

Detecting packaging material: end of roll
Independent of material: plastic/paper, transparent/colored, black/white

[Bottle Counting With Ultrasonic Sensors]

Measuring distance: avoiding collisions

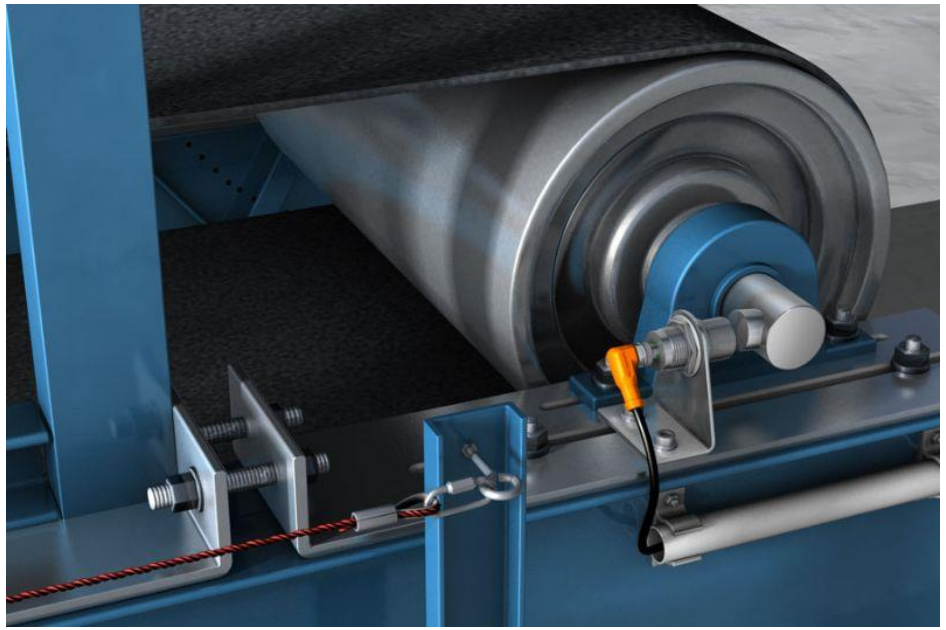


Level measurement

Application of Rotary Encoders

[degrees/angle/rotations/speed]

Speed monitoring
Distance measurement
Angle measurement



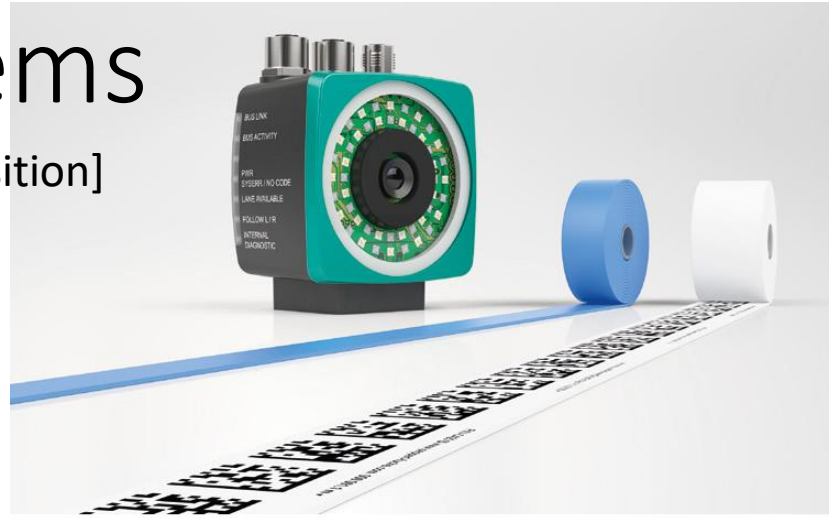
Conveyor belt speed monitoring

Propeller angle
Speed monitoring of generator
Angle z-axis

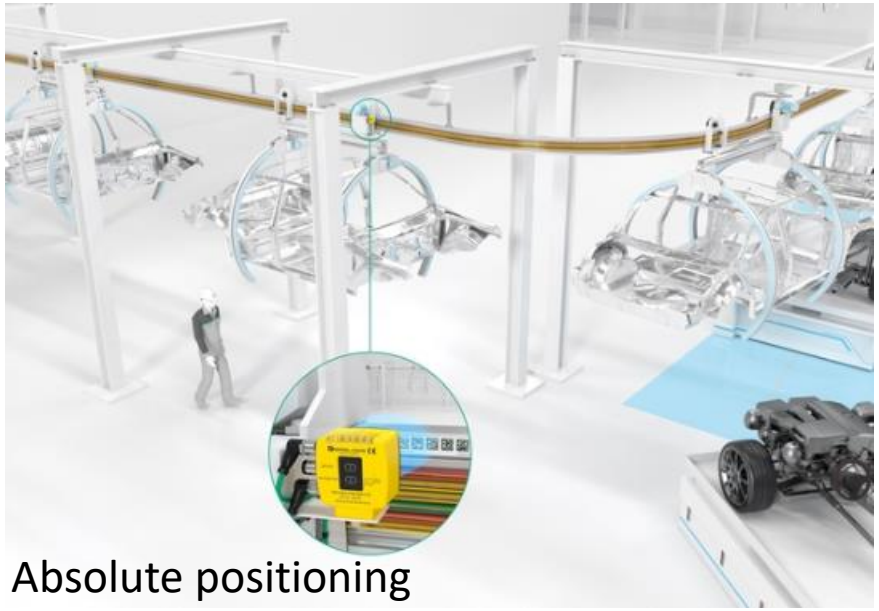
Images courtesy of Pepperl+Fuchs

Application of Positioning systems

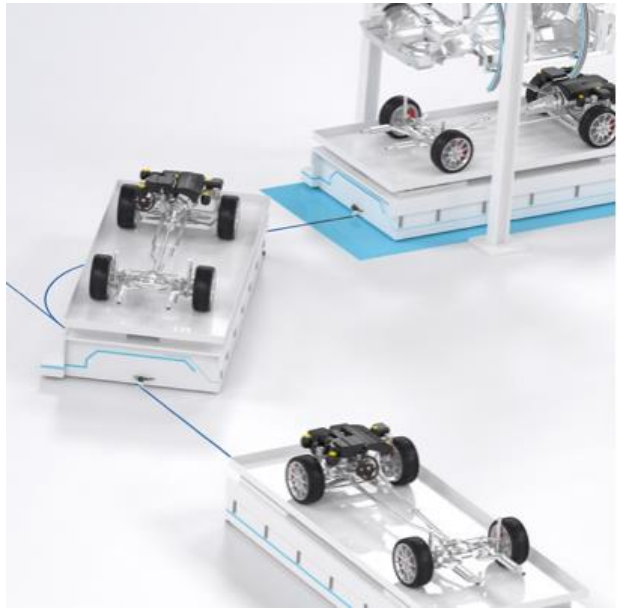
[location/position]



Absolute positioning (data-matrix code)
Navigation



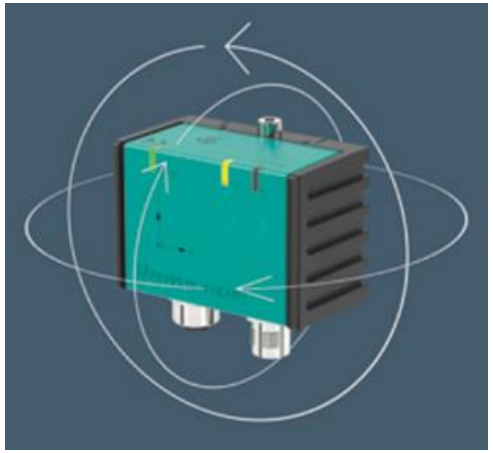
Absolute positioning

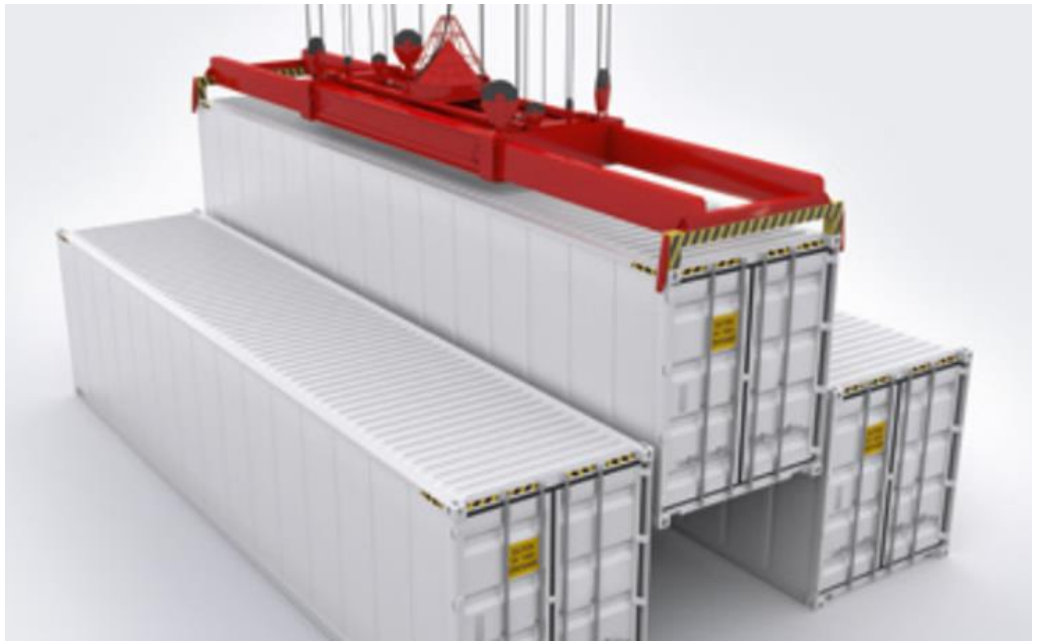


Navigation

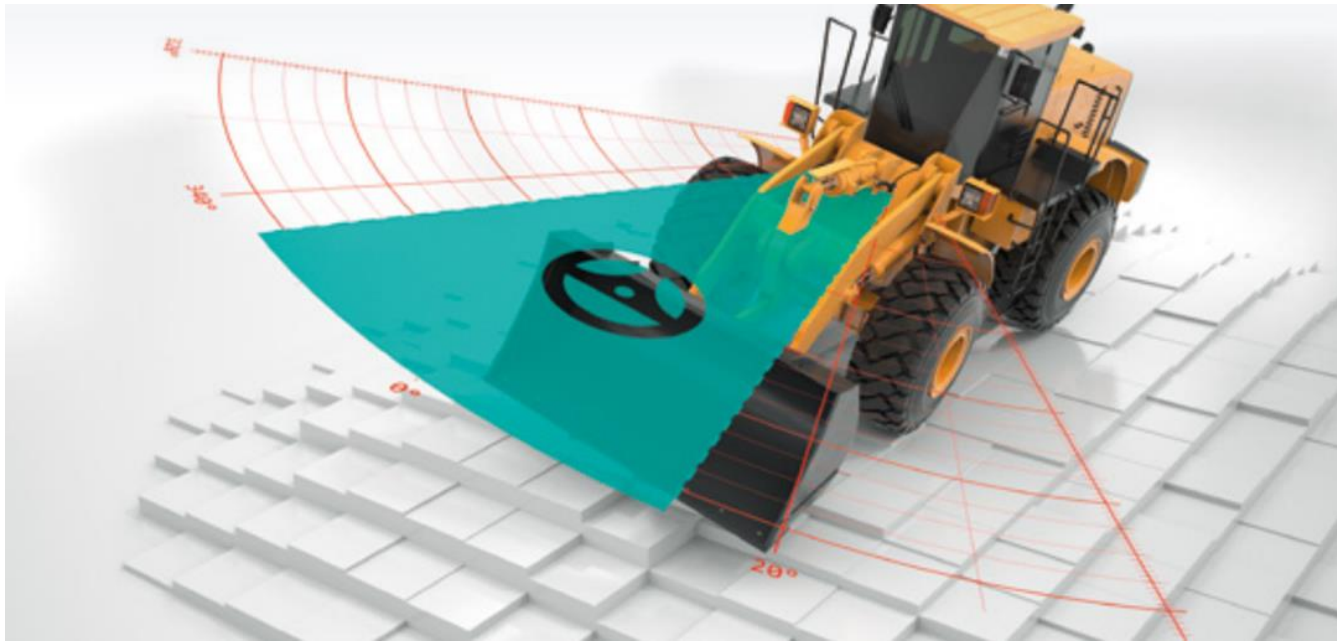
Inclination & acceleration sensors

[degrees, acceleration in 1 or more directions, axis]





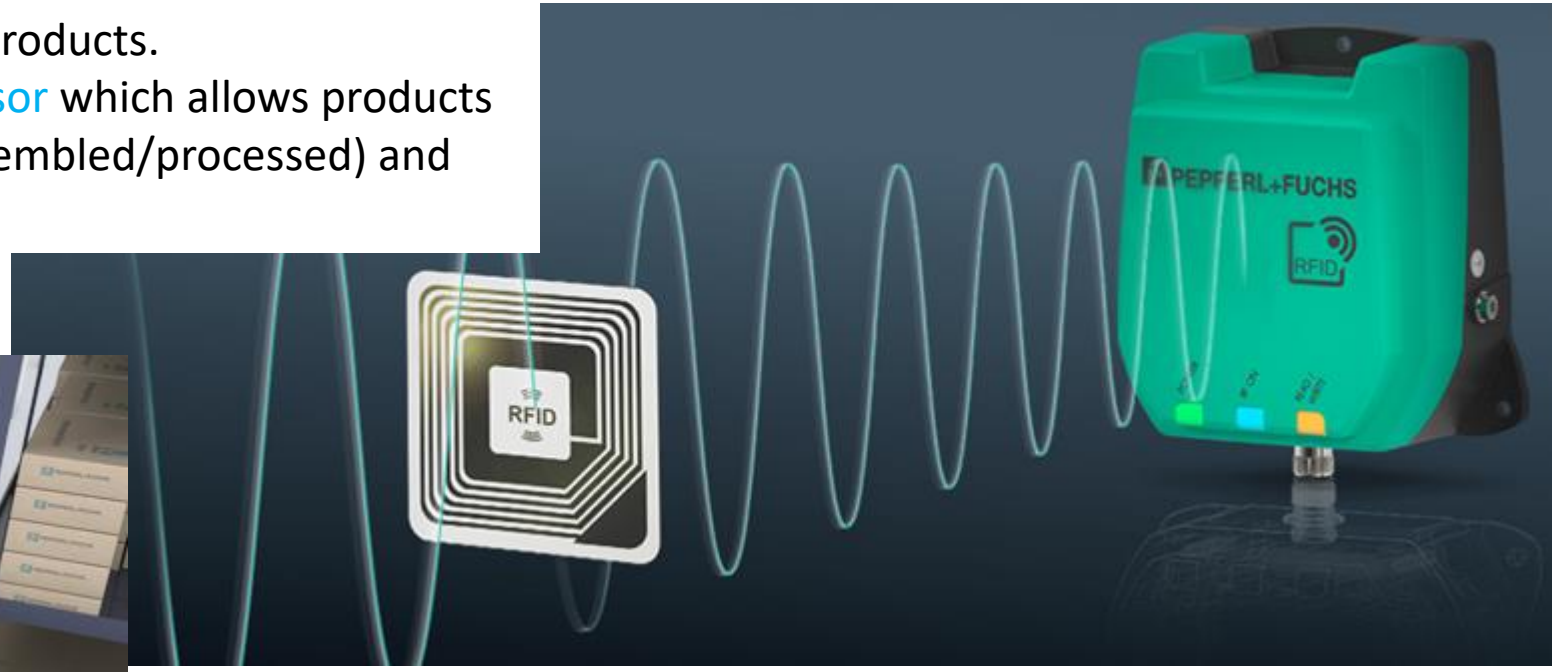
Container spreader angle measurement

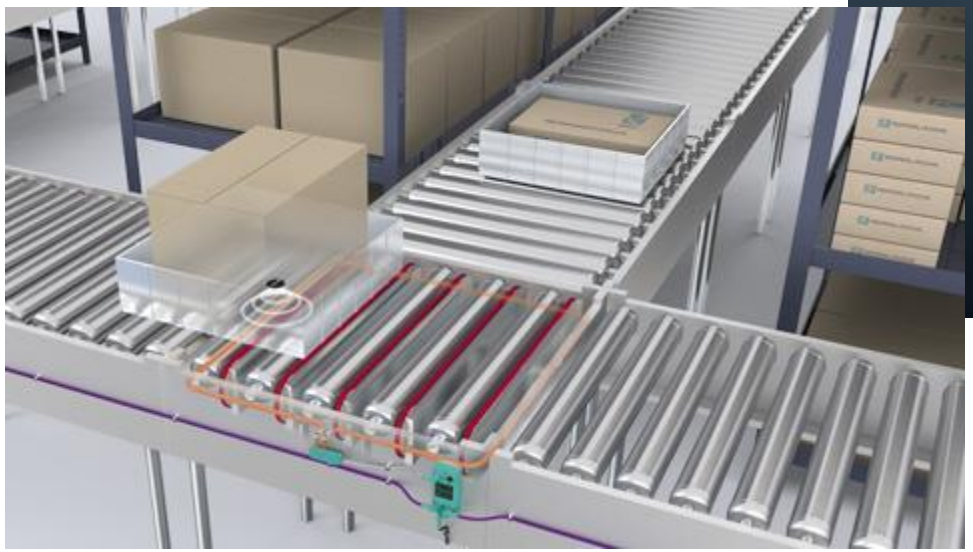


Using the data of the inclination sensor, the steering angle can be limited to prevent tilting

Identification systems (eg. RFID) [Tracking & tracing]

RFID tags are cheap; can be added to all products.
These can then be scanned by a RFID sensor which allows products to be uniquely identified (while being assembled/processed) and customized.





RFID F61 reading head
(Pepperl+Fuchs)

Images courtesy of Pepperl+Fuchs

Application of

Vision sensors

[Date/Lot Code Presence or Absence Detection]

04/12/2022

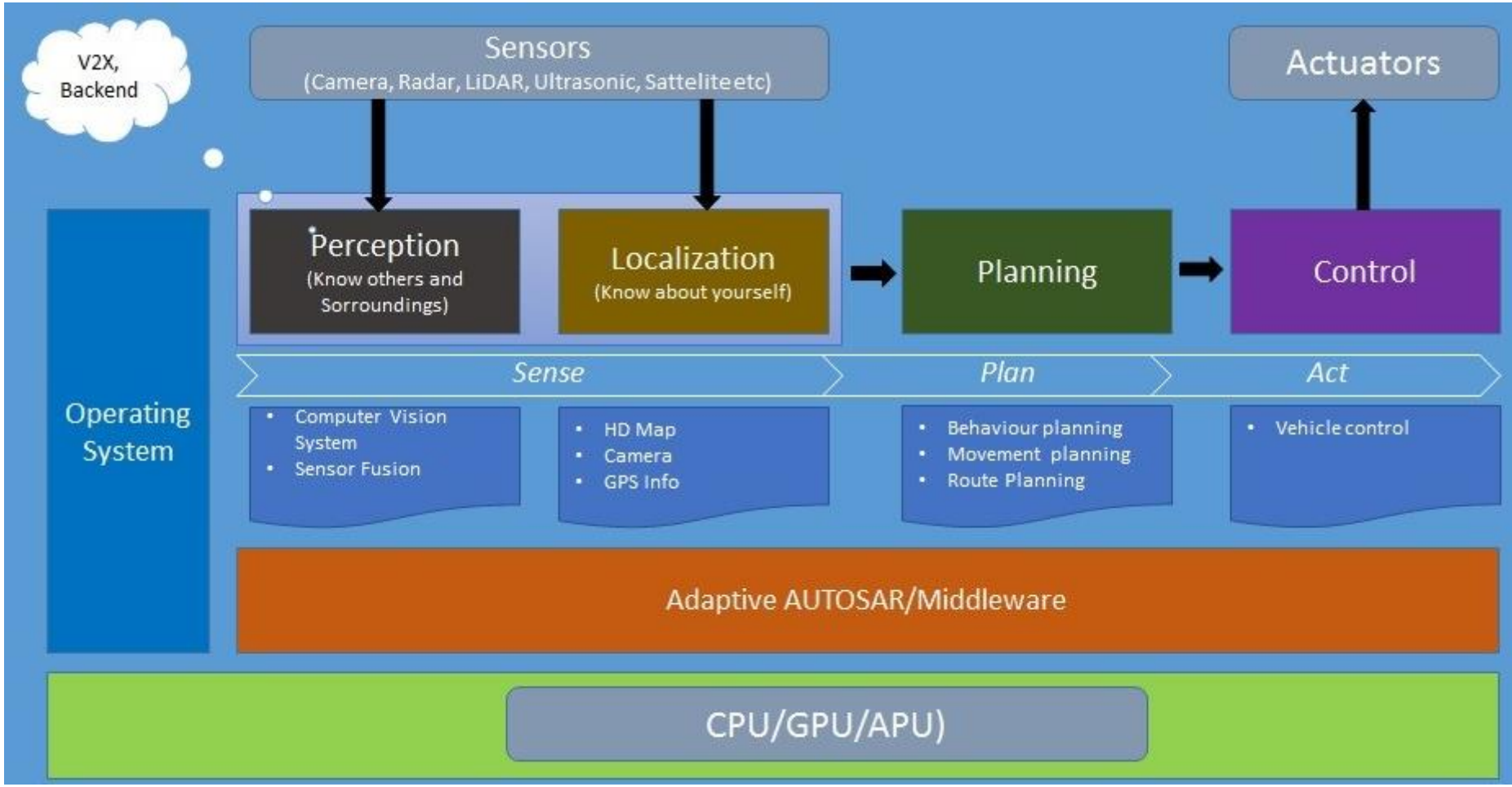
Context

- Always part of larger system, environment
- AGV's/mobile production platforms: need be aware of its environment
- Relying on sensor data alone does not provide the complete picture
- Sensor fusion with application of perception algorithms can improve this

Sensor Data for Mobile Robots

System

- Integration
- Hardware
- Software



Linkedin.com/pulse/high-level-embedded-architecture-autonomous-driving-akhilesh-misra

Drawbacks of use of sensors

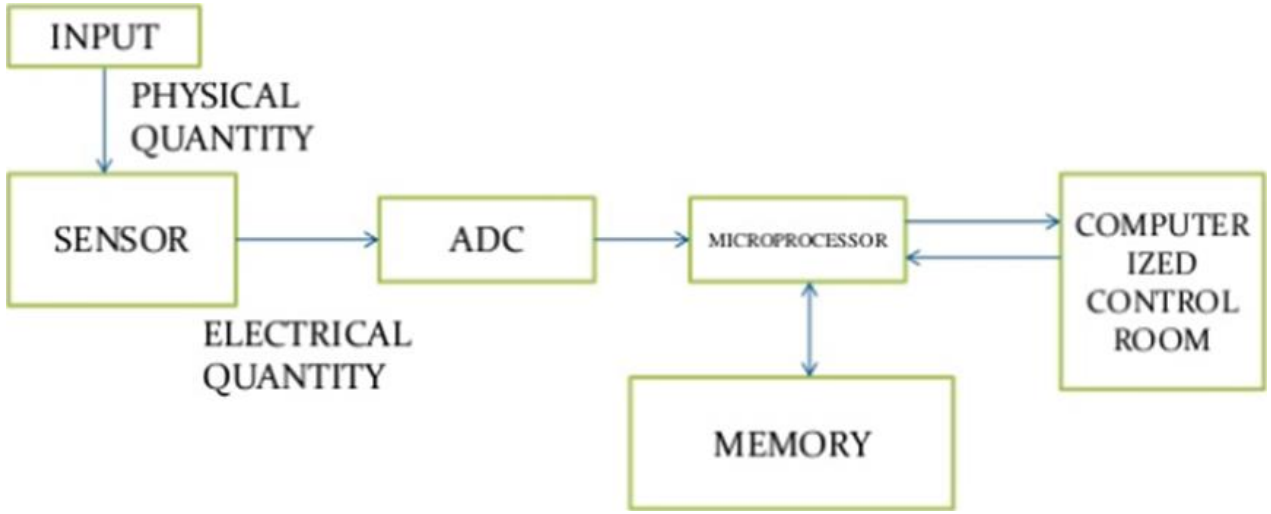
- Malfunctions
- Lifetime
- Interference (noise)
- Can be sensitive to
  - exposure to liquids, gas, etc.
  - changes in environment (e.g. change of temperature)
- Complexity
- Intrusion/security issues (connected sensors)

[Sensor malfunction to blame for rocket failure]

INDUSTRY 4.0

Includes a (micro)processor

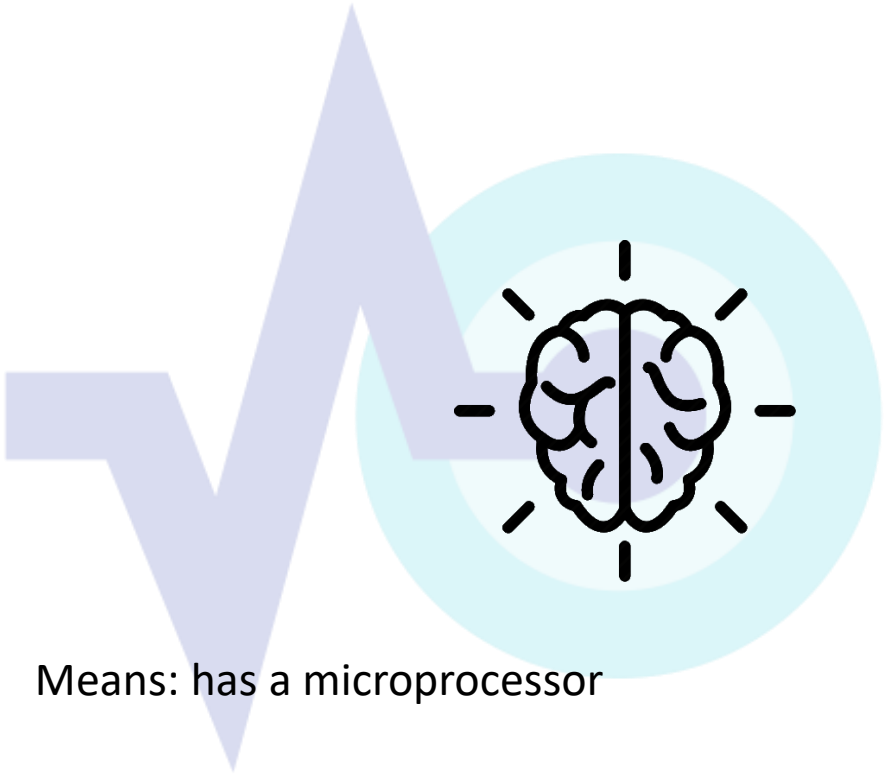
- Why switch to smart sensors?
  - Signal processing/interpretation
  - Linearize own output/error handling
  - Self calibration
  - Compensation for environmental changes



- Connectivity
  - Sensor networks
  - Wireless sensors (why?)

Smart sensors

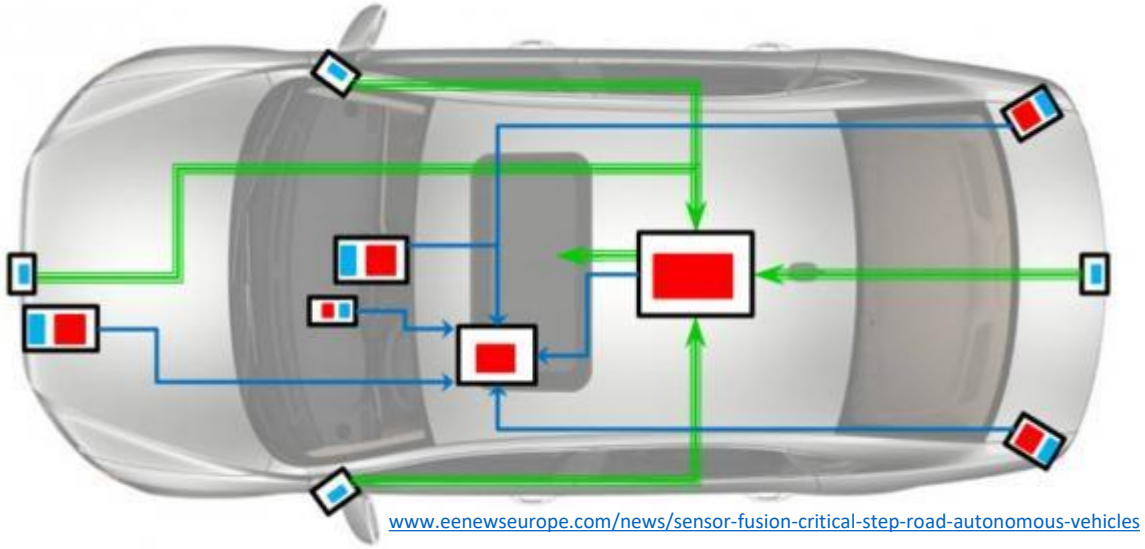
- Many definitions…
- What makes something smart?
- If it can:
  - Ignore/recover from faults/interference
  - Interpret/filter autonomously
  - Do some automated (pre)processing/recognition
  - Is connected



Means: has a microprocessor

ⓘ [Industry 4.0 and how smart sensors make the difference]

Sensor fusion



www.eenewseurope.com/news/sensor-fusion-critical-step-road-autonomous-vehicles

Combine information from different types of sensors to overcome strengths and weaknesses for different sensor types.

Example: A camera working in the visible spectrum has trouble in dense fog, rain, sun glare and the absence of light. Radar lacks the high resolution of today's imaging sensors.

www.androidcentral.com/realme-5s-48mp-quad-camera-setup-will-debut-india-november-20

ⓘ Sensor fusion: A critical step on the road to autonomous vehicles
Sensor fusion is the future

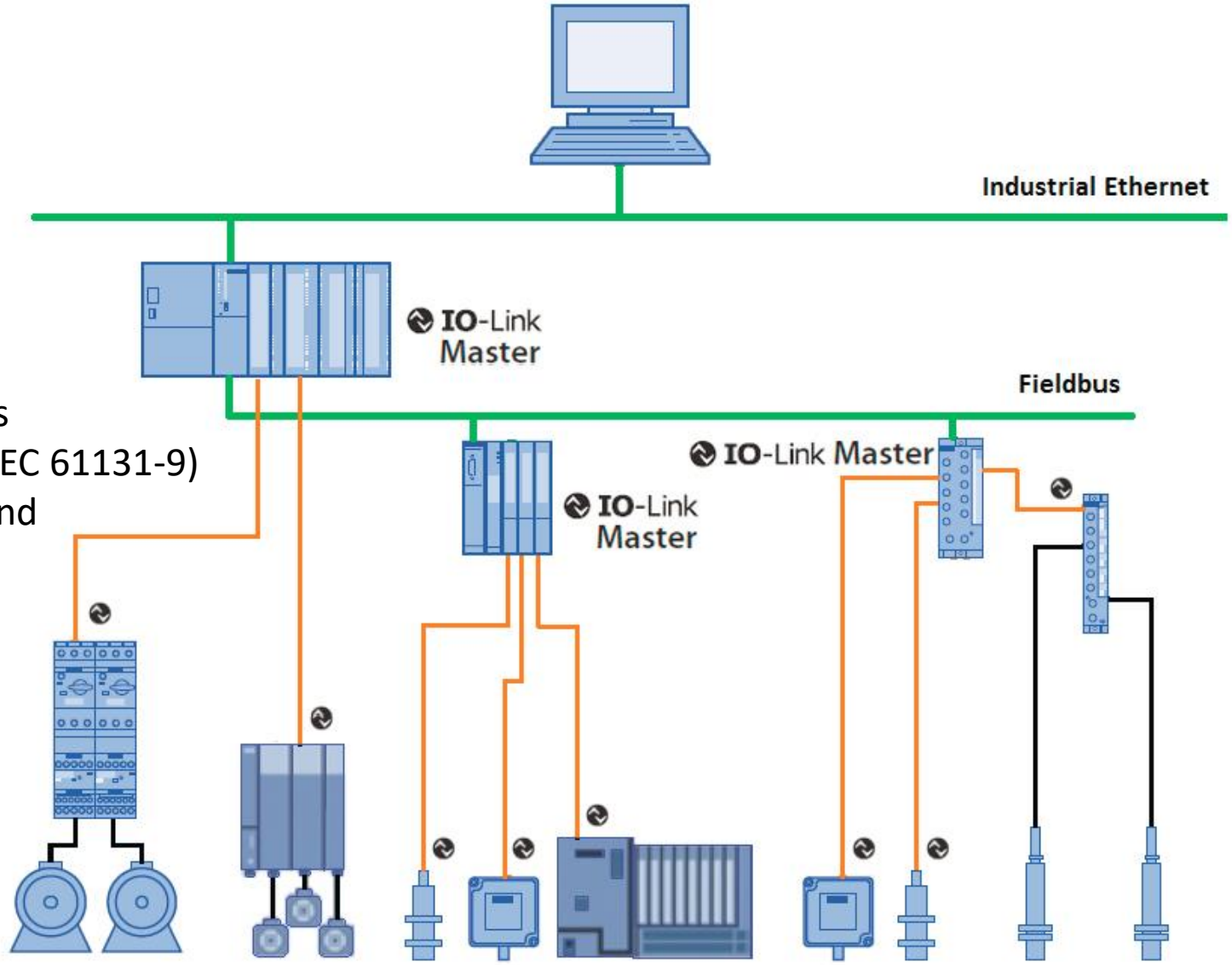
io-link.com

IO-Link

IO = Input Output: for sensors and actuators
Quickly realize Plug-and-play sensor networks
Robust standardized digital communication (IEC 61131-9)
Improves maintenance, remote diagnostics and parameter cloning

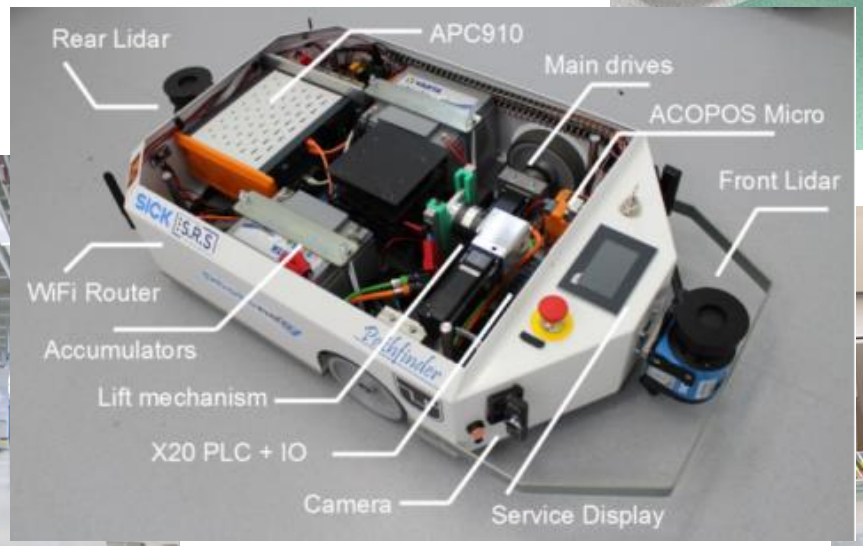
Challenges: old (analog) sensors & actuators

m8 / m12 connectors



Automated Guided Vehicles

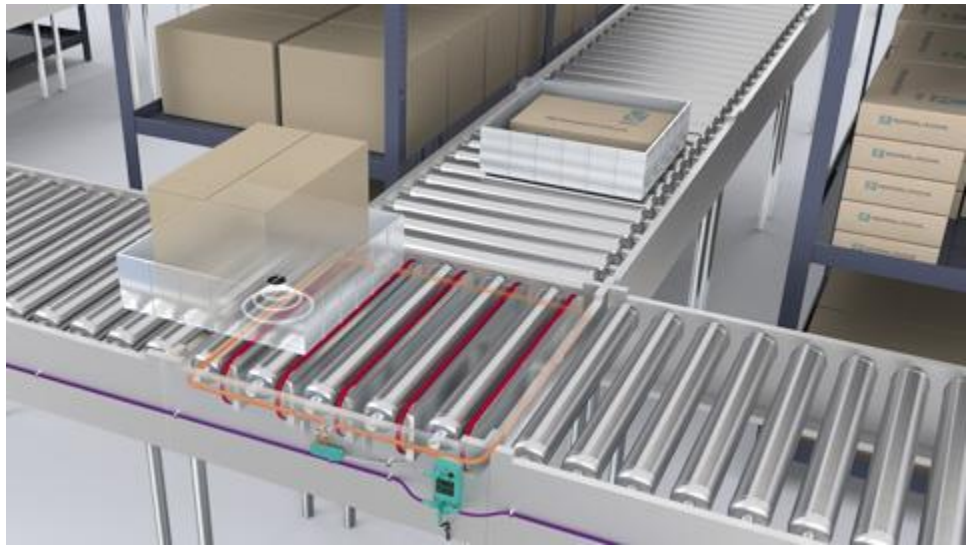
- Environment sensing
  - Optical and infrared cameras, laser, ultrasonic and lidar/radar
- Navigation & position sensing
- Motor sensing
- Sensor fusion



ⓘ [Radar Sensing for Driverless Vehicles]
[Industry 4.0 is picking up speed: Sensor solutions for mobile vehicles and carts]
youtube.com/watch?v=B1erx1BDdzQ
youtube.com/results?search_query=automated+guided+vehicle

Images courtesy of Sick

Implement mass customization
What do we need?



- Identify each product and its components while being manufactured
  - RFID, QR, barcode, or similar
- Track and trace (position, steps, inventory, status)
  - (Indoor) Position, GPS

System/shop floor:

- Linked/networked sensors
- Assembly units/cells: recognition of id
- Flexibility, variable throughput times
- Integrate dynamically and seamlessly into higher level IT systems

Custom: fit, coloring, design
(anything adopted to an individual/small group)

Images courtesy of Pepperl+Fuchs

Which factors can influence further integration of sensors on the shop floor?

- Increasing amount of information sensors can collect and share.
- Application of RFID sensor technology used in logistics operations improves identification of materials and products, e.g. to allow mass-customization.
- Location sensors allow for (realtime) traffic flow analysis and further optimization of production facilities and logistics
- Smart sensor networks allow for greater independent platforms (e.g. intelligent robots)
- This is not conclusive: think of others!

This afternoon: Practical session

Get a ‘sense’ of what is involved in selecting, implementing and testing sensors

Build a sensor, test it, do some measurements (determine accuracy, validity, reliability)

Evaluate/reflect

Apply what you learned to project assignment:
- What kind of questions can be formulated regarding sensors/sensing in the quick scan?
- What can be used to improve the “Educational quick scan Industry 4.0”? (e.g. the Measurement questions)
- What can be used from this lecture/practical to create and advise on how to achieve a greater industry 4.0 maturity (future state)?

Goto **vanslooten.com/i40/sensor-practical** to do the practical

QUESTIONS?

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